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John F. Golay, Provost and
Dean of the Graduate School

October 1, 1964

REPORTS CONTROL No. 1

TABLE OF CONTENTS

	Page
I. Summary Statement	2
II. Research Projects approved for Support (Abstracts)	3
The Paramagnetic Susceptibility of Lithium and Sodium Metal	3
Preparation of as-Triazine (1,2,4-Triazine) and Related Compounds	3
The Effect of Sensory Deprivation on Social Dominance in the Domestic Cat	4
Reaction of Sn (II) and Sn (IV) in Aqueous Solution	5
Decay of Cs ¹³⁴ to the Various Excited States of Ba ¹³⁴	5
Effect of Endocrines on Osteoporosis of Disuse	6
Cardiovascular, Respiratory, and Autonomic Nervous System Responses to Acute Hypoxia	6
Investigation of the Constitutive Equations for Multi-Phase Hypoelastic Materials	8
Production of Dispersion Alloys with the Aid of Ultrasonics	9
Measurement and Prediction of the Flow Field into a Propeller/Rotor System during Transition Flight	9
A Preliminary Study of the Effects of Strain Rate on the Mechanical Properties of Various Biological Materials	10
An experimental Investigation of the Effects of Hypervelocity Particles on Shielded and Unshielded Cellular Metallic Plates	10
III. Brief Progress Report as of October 1, 1963	11
Paramagnetic Susceptibility of Lithium and Sodium Metal	11
Preparation of as-Triazine (1,2,4-Triazine) and Related Compounds	12
The Effect of Sensory Deprivation on Social Dominance in the Domestic Cat	14

Table of Contents, continued

	Page
Reaction of Sn(II) and Sn(IV) in Aqueous Solution	17
Decay of Cs ¹³⁴ to the Various Exacted States	17
Effect of Endocrines on Osteoporosis of Disuse	18
Adrenalectomized rat Experiment	19
Parathyroidectomized rat Experiment	19
Cardiovascular, Respiratory and Autonomic Nervous System Responses to Acute Hypoxia	21
Investigation of the Constitutive Equations for Multi-Phase Hypoelastic Materials	24
Production of Dispersion Alloys with the Aid of Ultrasonics	24
An Experimental Study of Viscous-Flow Nose-Shape Effects on Impact Tubes	26
A Preliminary Study of the Effect of Strain Rate on the Mechanical Properties of Biological Materials	26
An Experimental Investigation of the Effects of Hypervelocity Particles on Shielded and Un- shielded Cellular Metallic Plates	27
IV. Expenditures and Commitments	29

I. Summary Statement

On October 1, 1963, the National Aeronautics and Space Administration granted to West Virginia University the sum of \$100,000 for the support of basic scientific research entitled: Space-Related Studies in the Physical, Life, and Engineering Sciences. The university accepted this grant and immediately circulated an announcement and instructions for submitting proposals for space-related research projects. (See appendix A). Proposals were received in the Graduate Office requesting a total of \$140,754.50.

An interdisciplinary committee was appointed by the president of the University to referee these requests for support in accordance with the NASA contract. This committee consisted of the following persons:

Dr. E. F. Byars, Chairman, Department of Theoretical and Applied
Mechanics

Prof. R. E. Shafer, Chairman, Department of Industrial Engineering

Dr. J. H. Thompson, Director, Bureau of Business Research

Dr. J. L. Hall, Chairman (acting) Department of Chemistry

Dr. J. K. Stewart, Chairman, Department of Mathematics

Dr. K. E. Penrod, Vice President, Medical Center

Dr. C. D. Thomas, Chairman, Department of Physics

Dr. C. A. Arents, Dean, College of Engineering

Dr. J. F. Golay, University Provost and Dean of the Graduate School

Twenty-three proposals were received and reviewed by the committee and twelve were approved for support. Each member of the committee evaluated each proposal with a view as to how well it corresponded with the purposes of the grant as published in the announcement.

It is difficult for academic personnel to initiate new research programs in the middle of an academic year. In many cases the research requires careful recruiting of assistants and collection of items of equipment preliminary to investigation. Hence five of the twelve projects were

not scheduled to start before June 1, 1964. All projects were to be completed on or before October 1, 1966 in accordance with the contract.

II. Research Projects approved for Support

The following projects were approved by the Committee:

1. The Paramagnetic Susceptibility of Lithium and Sodium Metal

Investigator: W. E. Vehse, PhD (Carnegie Tech 62), Assistant
Professor of Physics

Duration: 1 year

Funds: \$6,044.00

Abstract: Conduction electrons in a metal are weakly paramagnetic. Using a spin resonance technique devised by Schumacher and Slichter, we propose to reexamine some earlier, rather suspect, measurements of this paramagnetism in lithium metal. We also propose to examine properties of sodium metal closely allied to the spin paramagnetism in hopes of clarifying large discrepancies between theory and experiment. Finally we wish to investigate new avenues of research which may be profitably studied using this resonance technique.

2. Preparation of as-Triazine (1, 2, 4-Triazine) and Related Compounds

Investigator: Peter Popovich, PhD (Wash St U 61), Associate
Professor of Chemistry.

Duration: 15 months

Funds: \$4,811.00

Abstract: An attempt will be made to prepare unsubstituted

as-triazine via cyclization and condensation reactions from suitable compounds. It is proposed that glyoxal or related compounds and aminoguanidine, semicarbazide hydrochloride, or related compounds be condensed and cyclized to give intermediates from which as-triazine may be prepared. It is proposed that the aromatic character of as-triazine and related compounds be studied. In addition, the spectral, structural, and thermodynamic properties will be studied by making the compound available to specialists in these areas.

3. The Effect of Sensory Deprivation on Social Dominance in the Domestic Cat.

Investigator: James N. Shafer, PhD (Ohio St U 53), Associate
Professor of Psychology

Duration 1 year

Funds: \$2,562.00

Abstract: The social dominance of a group of 16 domestic cats will be tested in a food-competitive and a shock-avoidance situation. Following the establishment of a group social hierarchy selected animals will be maintained from 2-40 days in sound-shielded, light-proof cubicles. Following the period of sensory deprivation the animals will again be placed in the social dominance test situation and changes in dominance related to length of sensory deprivation and position on the dominance scale.

4. Reaction of Sn (II) and Sn (IV) in Aqueous Solution

Investigator: Armine D. Paul, PhD (U Calif 55), Associate Professor
of Chemistry

Duration: 1 year

Funds: \$4,816.00

Abstract: Sn (II) reacts with Sn (IV) in chloride solutions of low acidity to produce a yellow solution. In perchlorate solution the reaction is more extensive and under certain conditions a brown solid form. It is proposed to study the reaction qualitatively in the presence of other anions and cations, to study the chemical properties, physical properties and composition of the brown solid, and to try to develop procedures for separating the colored species in solution by ion exchange. If separation can be achieved, the composition of the colored species will be studied by ion exchange.

5. Decay of Cs^{134} to the Various Excited States of Ba^{134} .

Investigator: Raj G. Mendiratta, PhD (Penn St U 63), Assistant
Professor of Physics

Duration: 1 year

Funds: \$5,154.00

Abstract: Different experimenters have reported various decay schemes of Cs^{134} to the excited state of Ba^{134} by beta decay followed by gamma transitions. Recently, September 1963, a group at Louisiana State University has observed some new beta transitions but did not see a few gamma transitions that were reported before. The

log ft. values of the reported beta transitions have again been measured and are not found to be in close agreement with the previously estimated values. It is, therefore, desirable that a detailed investigation be made of the $\text{Cs}^{134} \rightarrow \text{Ba}^{134}$ decay using modern technique of solid state detectors, which are, by far, the most accurate beta detecting equipment known today.

6. Effect of Endocrines on Osteoporosis of Disuse

Investigator: H. A. Lindsay, PhD (U Toronto 55), Associate Professor of Physiology.

Duration: 1 year

Funds: \$5,336.00

Abstract: It is likely that osteoporosis of disuse would occur under conditions of weightlessness. We will test the hypothesis that hormones are a mediator of the removal of mineral from bone during the production of osteoporosis of disuse. Rats will be subjected to sciatic nerve section to produce the osteoporosis. Changes in the bones will be assessed by x-ray examination and measurement of the various dimensions, characteristics of stress and strain, and of breaking point. The foregoing will be contrasted in animals intact in the endocrine sense and in those which have been hypophysectomized or parathyroidectomized. To the best of our knowledge this seemingly manifest experiment has not been done.

7. Cardiovascular, Respiratory, and Autonomic Nervous System Responses to Acute Hypoxia

Investigator: Thomas D. Darby, PhD (Med C S Car 57) Associate Professor of Pharmacology

Funds: \$9,041.00

Abstract: It is known that the sympathoadrenal system is stimulated and large amounts of epinephrine are released from the adrenal medulla when the dog is exposed to conditions of severe hypoxia. The relationships that exist between energy metabolism and cardiac muscle activity under conditions of sympathoadrenal stimulation are not understood. Raab suggests that catecholamine stimulation of the myocardium leads to an oxygen waste. Katz has suggested that the endogenous release of the catecholamines elicits a "stress adapting mechanism" which is responsible for a more efficient myocardial utilization of oxygen. An increase in the quantity of oxygen present in cardiac tissue following the administration of the catecholamines, despite electrocardiographic changes which suggested myocardial ischemia, led Sayen and coworkers to the conclusion that these agents could increase anaerobic metabolism in heart muscle.

In the present studies myocardial function, hemodynamic changes, respiratory stimulation, oxygen utilization and lactate production will be correlated with catecholamine levels in the inferior vena cava and peripheral blood. In the initial experiments the terminal event in acute hypoxia will be studied. In subsequent experiments the effects of drugs known to alter sympathoadrenal function will be studied on the terminal event. The experiments should provide information about the effects of space environment on

organisms and living systems. The metabolic changes occurring in stress situations will be evaluated. Such studies could aid in the development of life support and protection systems in spacecraft.

8. Investigation of the Constitutive Equations for Multi-Phase Hypo-elastic Materials.

Investigator: Robert D. Snyder, MSME (Clemson C 59), Instructor in
Theoretical and Applied Mechanics

Duration: 1 year

Funds: \$3,901.00

Abstract: A class of materials, defined as hypo-elastic, may be considered to have a short memory insofar as their mechanical response is concerned. This consideration has led to a constitutive equation in the form

$$\text{Stress rate} = f(\text{stress, strain rate}).$$

The generality of such a constitutive equation is easily seen from the fact that many elastic materials are included as sub-classes of hypo-elastic materials.

The purpose of this project is to investigate the constitutive equation of a heterogeneous hypo-elastic material composed of two or more hypo-elastic materials. In particular, an attempt will be made to develop a method by which an effective constitutive equation of the composite hypo-elastic material can be expressed in terms of the constitutive properties of the individual materials. This investigation is viewed as an initial step in eventually

being able to determine or predict an effective constitutive equation for non-homogeneous non-isotropic hypoelastic materials, and should be a worthwhile contribution to the general theory of constitutive equations of continua.

9. Production of Dispersion Alloys with the Aid of Ultrasonics.

Investigator: H. V. Fairbanks, MS (Mich St U 39), Professor of
Metallurgical Engineering

Duration: 18 months

Funds: \$6,528.00

Abstract: Dispersion alloys have come into prominence as space vehicle material due to their ability to retain relatively high strength at elevated temperatures. They are currently being produced by the powder metallurgy process which inherently produces an initial porous structure and limits to some extent the size and shape of the part produced. The use of ultrasonic energy in the production of these alloys would seem a promising alternative, since the alloys could be produced without the size and porosity limitations imposed by the powder metallurgy process.

10. Measurement and Prediction of the Flow Field into a Propeller/Rotor System during Transition Flight.

Investigator: Richard E. Walters, MSAE (WVU 63), Instructor in
Aerospace Engineering

Duration: 1 year

Funds: \$4,502.00

Abstract: The research program outlined in the proposal is designed to provide an accurate method for predicting the thrust, normal force, pitching moments, yawing moments and torque for propeller/rotor systems during transition flight. The lack of this information places a serious limitation on the design process for Vertical Take-Off and Landing aircraft with tilt-propeller or rotor systems.

11. A Preliminary Study of the Effects of Strain Rate on the Mechanical Properties of Various Biological Materials

Investigator: James McElhaney, MSME (U Pa 60), Research Associate

Duration: 1 year

Funds: \$3,807.00

Abstract: It is proposed to institute a study of the effect of strain rate on the properties of various biological materials (bone, cartilage and special tissue types). A specially designed testing machine and high-frequency response instrumentation will be used to obtain stress-strain information over a wide range of strain rates. The data will be analyzed according to recent advances in the theory of Biorheology and an attempt made to develop suitable mathematical models that describe the behavior of these materials.

12. An Experimental Investigation of the Effects of Hypervelocity Particles on Shielded and Unshielded Cellular Metallic Plates

Investigator: Emery L. Kemp, PhD (U Ill 62), Associate Professor of
Civil Engineering

Duration: 9 months

Funds: \$3,491.00

Abstract: It is proposed to subject targets of cellular metallic materials to the impact of particles simulating the mass and volume of small meteoroids. The acceleration of the targets and particles to relative velocities in the meteoric range would be accomplished by explosive and gaseous devices. When sufficient data are collected the results would be correlated into design equations governing the shielding and skin thickness required for adequate meteoroid protection of thin-walled craft in orbital and interplanetary flight.

III. Brief Progress Report as of October 1, 1963.

1. Paramagnetic Susceptibility of Lithium and Sodium Metal.

W. E. Vehse

Two relatively significant experiments have been performed to date. The present ultrasonic generator has proved inadequate and a satisfactory generator will be ordered before September 18. A Pound-Knight oscillator and lock in amplifier have been constructed and are operating satisfactorily. Results of the measurement of the susceptibility of lithium metal in inferior samples was reported at the April meeting of the West Virginia Academy of Science. To check the equipment, the Knight shift in sodium metal at room temperature was measured, verifying published results. We are now ready to attempt the desired low temperature (4° K) measurements.

Refined lithium measurements should be ready within 6 months and this phase should be completed within a year. Low temperature studies including relative susceptibility measurements, impurity studies and relaxation time measurements are planned for early 1965.

A short time will be spent examining the feasibility of doing Knight shift work on a manganese chromium system with a view to preparing another research proposal.

It is planned to present the results at a meeting of the American Physical Society and to submit a paper for publication in an appropriate journal.

The impurity studies and the low temperature relative susceptibility measurements are two aspects of the present research which are definitely suited for long range research effort and funds will be sought to continue these investigations well beyond the duration of the present grant.

2. Preparation of *as*-Triazine (1,2,4-Triazine) and Related Compounds.

Peter Popovich

The first experiments concerned the condensation of aminoguanidine bicarbonate with glyoxal to yield 3-amino 1,2,4-Triazine (called I hereafter) and the removal of the 3-amino group. The removal of the 3-amino group was first attempted by classical diazotization procedures and replacement of the group, in the presence of hypophosphorus acid, with hydrogen. In a second series of experiments a non-aqueous solvent was used for the diazotizing medium. Glacial acetic acid was used as the solvent and cuprous oxide in the presence of sulfuric acid was used as the reducing agent. In a third series of experiments, an attempt was made to prepare a stable diazonium fluoroborate with the expectation that it could be decomposed to give a fluoro-compound or converted to the desired as-triazine.

Several experiments were performed to further characterize the amine by preparation of suitable amine derivatives. An attempt was made to react the amine with benzaldehyde and anisaldehyde in order to prepare a Schiff-base. Attempts were made to react I with acetic anhydride,

acetyl chloride, and benzoyl chloride. The latter under the Schotten-Baumann conditions. None of these gave the expected derivative. Another series of experiments were performed in an attempt to prepare as-triazine by cyclization of ethylsemicarbazinoacetate in the presence of sodium ethoxide to give 3,5-dioxy-1,6-dihydro-1,2,4-triazine and conversion of the latter compound to as-triazine. Ethyl semicarbazine-acetate was prepared by the reaction of potassium chloroacetate with semicarbazide hydrochloride and esterification of the resulting compound with ethanol.

At this time, it appears that the 3-amino group does not function as a normal group as in aromatic amines and that it cannot be removed by normal deamination procedures. Reaction temperatures for the diazotization and deamination were varied from 0° C to minus 30° C. It appears that the ring structure is destroyed during the reaction.

Experiments with 3,5-dioxy-1,6-dihydro-1,2,4-triazine (II) will be continued. After the ring is formed an attempt will be made to convert it to an aromatic system by the use of bromine. Experiments to determine the fate of the amino-triazine (I) during diazotization will be conducted.

The work is in the early stages of development (fourth month of a fifteen month grant). Significant results of this work will be submitted to the Journal of Organic Chemistry or to the Journal of Heterocyclic Chemistry.

Present indications are that the work could be extended to prepare many interesting substituted as-triazines which have not been reported to date.

3. The Effect of Sensory Deprivation on Social Dominance in the Domestic Cat.

James N. Shafer

The effect of sensory deprivation on the dominance behavior of domestic cats was investigated in two separate experiments involving widely desperate test situations. The two test situations were (1) food competitive behavior and (2) shock avoidance. The two experiments will be summarized separately.

Experiment #1 - Effect of sensory deprivation on food competitive dominance behavior.

Subjects: The subjects were eight domestic cats selected from a colony of animals maintained by the psychology department.

Apparatus: The subjects competed for liver in the Wisconsin General Test apparatus. Sensory deprivation was achieved by isolating the subjects in chambers 32" x 24" x 32" high constructed of $\frac{1}{2}$ " celotex.

Procedure: The Ss were pre-trained to respond in the WGTA until each animal was proficient in obtaining food. Following the pre-training the eight subjects were tested by the method of paired comparisons every third day until a total of six comparisons had been completed. In each pairing the Ss competed five separate times for the highly preferred food (liver).

Dominance was determined by the number of pieces of liver obtained by each S. The S obtaining the greatest number of pieces of food was ranked first in the hierarchy, the S obtaining the second greatest number was ranked second, etc.

Following the six paired comparisons the Ss were placed in isolation for 21 days. On the seventh, fourteenth and twenty-first days the Ss were removed from isolation and again tested in the WGTA by the method of paired comparisons.

Results: The stability of the hierarchy before and after isolation was tested by Kendall's coefficient of concordance and X^2 . The pre-isolation and the post-isolation distribution of food for all comparisons differed from chance or rectangularity at or beyond the .001 level as tested by X^2 . Kendall's coefficient of concordance computed separately on both pre-and post-isolation comparisons revealed a highly stable (P. .001). From the data it can be concluded that 21 days of isolation has no differential effect on the dominance behavior of cats in a food competitive test situation.

Experiment #2 - Effect of sensory deprivation on shock avoidance dominance behavior.

Subject: The subjects were seven domestic cats selected from a colony of animals maintained by the psychology department.

Apparatus: The animals were tested in an aluminum compartment 24" x 36" x 32" long. The floor of the compartment was made of 3/16" stainless steel rods $\frac{1}{2}$ " on center. A wooden perch or platform 10" x 3 $\frac{1}{2}$ " x 3/4" thick was placed 17" above the grid. Stainless steel rods were also placed on the perch. Power to the grids was monitored by a Davis Scientific Corporation Shock Power Supply and Grid Scrambler. The current and voltage was varied for each individual animal. A door bell buzzer and a 100 watt bulb were used as the conditioned stimulus. Both the CS and the UCS were automatically programmed and timed.

Procedure: Each animal was conditioned to avoid the shock by responding to the light and buzzer which preceded the onset of the shock by 5 seconds. Each animal was tested 25 trials a day until they reached the criterion of seven successful avoidance responses in any 10 trials. When all animals had reached this criterion they were given 100 additional trials to assure proficient performance for all animals.

Following the training period the animals were placed in pairs in the shock compartment and the CS followed 3 seconds later by the UCS was presented. All possible paired comparisons of the seven Ss were tested for five trials per pairing for a series of three paired comparisons. The animal on the perch, which was large enough for only one animal, at the end of the 3 second period of shock was considered the dominant animal. Following the pre-isolation dominance tests all subjects were placed in isolation for 21 days. On the seventh, fourteenth and twenty-first days the Ss were removed from isolation and again tested in the shock compartment by the method of paired comparisons.

Results: The data has not been completely analyzed but a preliminary analysis has failed to reveal a stable dominance hierarchy on either pre- or post-isolation dominance test. The successes seem to be randomly distributed among the seven animals in each of the three pre- and post-isolation tests. It is therefore concluded that a dominance hierarchy is not established in cats as tested by shock avoidance either prior to isolation or as a result of 21 days of isolation.

There are several significant features of the investigations undertaken to date. They are:

- (1) Stable dominance hierarchies are formed among a group of eight cats tested in a food competitive situation.
- (2) Dominance hierarchies are not formed among cats tested in a shock avoidance situation.
- (3) A twenty-one day isolation period does not interrupt the established dominance hierarchy.
- (4) A twenty-one day isolation period does not change the unstructured dominance hierarchy, as tested in a shock situation, to a structured hierarchy.

The two experiments will be submitted to an appropriate psychological journal. A collateral study initiated by the interest of one of the investigators working on this grant will be submitted to be read at the spring meetings of the Southeastern Psychological Association and later submitted for publication.

The two graduate students who worked on the project have developed an interest in the problem and plan further research in the area. In addition a third graduate student who was indirectly associated with the project now has a post-doctoral fellowship and is planning research in the area.

4. Reaction of Sn(II) and Sn(IV) in Aqueous Solution.

Armine D. Paul

This research was scheduled to start in June 1964 with a graduate student committed to the project. Unfortunately, the student was unable to enroll during the summer and Dr. Paul applied for, and received, permission to postpone starting the project until September 1, 1964. The necessary chemicals and supplies were procured during the summer. The project is now active, but it is too early to report progress.

5. Decay of Cs^{134} to the Various Exacted States.

Raj G. Mendiratta

This project was scheduled to start July 1, 1964. During the summer, however, Dr. Mendiratta returned to India and when he attempted to return, encountered immigration difficulties. He has not yet been able to reenter this country. Dr. Atam Arya has recently been appointed to direct the remainder of this research. Dr. Arya (Ph. D. Penn State, 1960) has been working with Dr. Mendiratta on this and similar problems, and, using the same team of research assistants, will be able to proceed

without interruption. Planning research procedures and acquisition of suitable apparatus has been completed during the summer but the project was held up pending the decision on Dr. Mendiratta's visa. It is now active.

6. Effect of Endocrines on Osteoporosis of Disuse.

H. A. Lindsay

1. Preliminary experiments were carried out to test the accuracy of our methods.

a. Two methods of breaking the bones were tried. First the ends of the femurs to be broken were laid on two supports and a hook connected to a pan of weights was applied to the middle of the bone; additional weights were added until the bone broke. We then found that the use of a 1 RPM electric motor attached to a spring scale which was in turn hooked to the bone superior to the above method. The rate of application of weight to a bone is an important factor in determining its strength. The use of a motor assures a constant rate of application of force whereas static loading of a bone does not.

b. Several types of materials were tested as casts on the ends of the bones to prevent their collapsing during the breaking process. "Improved stone," a dental casting substance, worked very well.

c. X-ray studies were attempted to determine the density differences between normal and denervated limb femurs. We could observe no significant difference using a standard hospital x-ray.

2. Hypophysectomized rat experiment.

Equal numbers of control and experimental animals were used. The sciatic and femoral nerves were surgically sectioned on one side.

The opposite leg served as a control. A significant difference in total bone weight and force necessary to break the bones was found between intact and "denervated" femurs in both control and hypophysectomized rats. When comparing the per cent differences of these values for control with the per cent differences in the hypophysectomized animals there was no significant difference.

3. Adrenalectomized rat experiment.

The same methods were used as in the hypophysectomized rat experiment. Due to poor survival of our first population of animals in this experiment the data was not conclusive; therefore, we obtained a second group. No significant differences between the per cent difference of intact and "denervated" femurs from control and experimental rats were found in total bone weight.

4. Parathyroidectomized rat experiment.

The procedure used was the same as that in the two previous studies. Femurs from the control and experimental groups have been removed from the animals and are now being dried.

Our original objective was to test the hypothesis that hormones are a mediator in the removal of nitrogen and mineral from bone during the production of osteoporosis of disuse. Our data indicates that removal of the hypophysis and the adrenal gland causes a loss in the total weight, strength, length and diameter in both femurs but this has no significant effect on the production of osteoporosis caused by sciatic and femoral "denervation". The degree of atrophy in both intact and "denervated" femurs seems to be most pronounced when the hypophysis is removed.

Other investigators have shown that when estradiol and testosterone are given rats in which one limb has been "denervated" and the other

left intact, there is a decrease in the difference in weight and strength between the bones of the intact and paralysed limbs. This could be due to the anabolic effect of the hormone on the bone or it could be that the effect of the hormone on the vascular system of the intact limb and the denervated limb may be different. If it were a case of simply disturbing the protein anabolic-catabolic hormone balance, we should have achieved the same results by removing the catabolic influence of the adrenal gland. However, we observed no such effect when we did this.

Description and statement of objectives of research to be conducted for the balance of grant period:

1. The parathyroidectomized rat experiment will be completed using the same procedure as in previous experiments.
2. A group of hypothyroid rats will be treated as described also.

Plans for publication of results:

After completing experiments already begun we anticipate publishing a paper on the hypophysis, adrenal, thyroid experiments; a second paper on the parathyroid experiment will follow.

Possibilities for expansion of project:

In the near future, we plan to apply for a grant, with the department of Theoretical and Applied Mechanics of West Virginia University, to study another possible mechanism (piezoelectricity) linking bone resorption with disuse. It has been shown that when stress is applied to bone electric potentials are generated and their amplitude is dependent on the rate and magnitude of the bone deformation. Preliminary studies are presently being conducted by T.A.M.

Our work thus far has made us acutely aware of our need for more accurate techniques in measuring stress in bone. A combined research

effort between the departments of physiology and theoretical and applied mechanics would provide a means whereby a biomechanical problem could be studied from both the physiological and engineering points of view.

7. Cardiovascular, Respiratory, and Autonomic Nervous System Responses to Acute Hypoxia.

T. D. Darby

To date, a total of 36 experiments have been carried out. These experiments have studied the cardiovascular changes that occur with hypoxia, hypocarbia, hypercarbia and death due to anoxia.

Effects of changes in $p\text{CO}_2$ on myocardial contractility, cardiac size, and hemodynamic work. While it has long been known that CO_2 depresses myocardial contractility when this parameter of myocardial function is measured at a fixed initial length, the changes in myocardial contractility that can occur under in situ conditions have not been investigated. As the arterial $p\text{CO}_2$ was increased from hypocarbic levels of 20 mm Hg to normal values (40 mm Hg) and to hypercarbic values of 60 to 80 mm Hg, there was a progressive passive dilation of the myocardium. The size of the heart increased with increments in $p\text{CO}_2$ under conditions of a fixed pressure load. Since the force on the myocardial wall is the product of the intraventricular pressure times the surface area of the ventricular cavity, the increase in chamber size with increased $p\text{CO}_2$ levels would increase the tension work load on the myocardium.

Changes in pulmonary vascular resistance with hypoxia and anoxia. Pulmonary vascular resistance is increased by a decrease in inspired $p\text{CO}_2$. Preliminary studies indicate the marked myocardial dilation seen with hypoxia is more due to increased pressure work load on the myocardium than due to passive dilation as seen with increased $p\text{CO}_2$

values. Death due to anoxia is accompanied by a marked increase in pulmonary vascular resistance. The increase in pulmonary artery pressure is greater than would be expected from the rise in left atrial pressure seen with left ventricular impairment elicited by the anoxia. It is suggested that an increase in pulmonary vascular resistance is the primary cause of a decrease in cardiac output seen in the initial and terminal periods of anoxia.

Myocardial changes seen with hypoxia and anoxia. The myocardial changes seen with hypoxia and anoxia seem to be more related to increments in hemodynamic parameters than to passive changes in myocardial tone. The infundibular area of the right ventricle is markedly stretched by the increased work load placed on the right ventricle during periods of hypoxia. There is very little shortening of the muscle in this area of the myocardium during systole. Marked hypoxia depresses the developed tension of all areas of the myocardium during systole. There is a decrease in the rate of tension loss during diastole under conditions of hypoxia. This supports the view that relaxation of muscle is an active process. The rate of tension development during systole is less effected by hypoxia than the rate of tension decrease during diastole. Partial sustained contraction is found with hypoxia.

Sympathoadrenal changes during hypoxia, anoxia, hypocarbia and hypercarbia. The cardiovascular manifestations of increased sympathetic autonomic tone under conditions of hypoxia and anoxia occur significantly later than under conditions of hypercarbia. The heart rate changes are less pronounced during periods of hypoxia and sympathetic autonomic stimulation than under conditions of hypercarbia. Anoxia is usually accompanied by marked bradycardia even in periods of increased developed tension due to sympathetic stimulation. Hypercarbia is usually accompanied by tachycardia. Myocardial asystole or ventricular fibrillation

as the terminal event of oxygen lack occurs significantly later if the animal is hypocarbic than if hypercarbia or normal $p\text{CO}_2$ values are present.

It is felt that these experiments are adding significant knowledge to our understanding of cardiac function under conditions that can occur during periods of manned space flight. It is planned to continue these experiments and to add to our knowledge of hemodynamic and autonomic changes under these conditions. The information gained in these experiments can add significant knowledge to the field of medicine in general, but more specifically the field of anesthesia.

The experiments to be conducted during the balance of the grant period will be centered around pulmonary vascular changes which occur during periods of anoxia and hypoxia. The effects of these pulmonary vascular changes on the right ventricle will be evaluated.

The manuscript dealing with the points outlined above will be completed within the month of September. A preliminary report of this material will be presented at the American Heart Association Meetings in Atlantic City in October. A full manuscript will be prepared early in 1965.

Under high G forces the heart of monkeys have been shown to be markedly elongated. During takeoff and under conditions of weightlessness the configuration of the heart could be changed. The effects of stretch on the muscle of the ventricles could be studied with the available equipment and personnel of this laboratory. The importance of changes in the size and shape of the heart in hemodynamic considerations is becoming increasingly clear.

During the coming year considerable attention will be given to the effects of anoxia and hypoxia on these parameters of heart size and

shape. Special attention will be given to the outflow tract of the right ventricle.

8. Investigation of the Constitutive Equations for Multi-Phase Hypoelastic Materials.

Robert D. Snyder

The major hurdle in the resolution of this problem has been overcome, that of developing some basic variational, uniqueness, and extremum theories for elastic behavior analogous to the theories of classical elasticity. It was necessary to impose some restrictions on the exact form of the constitutive equations. It is too early to gauge the severity of these restrictions.

Research to date indicates that this study will form the basis of a future research proposal involving experiments with actual multi-phase materials. This proposal will be directed toward some manufacturers of jet age materials in an effort to obtain their interest and financial support.

Results obtained so far indicate that enough basic knowledge of multi-phase materials will be obtained to enable the principal investigator to undertake some specialized investigations of interest to a variety of agencies in the industrial, military, and governmental areas.

Plans are being made to submit some of the results already obtained for publication. It is expected that several publishable articles will form the completed work of this project.

9. Production of Dispersion Alloys with the Aid of Ultrasonics.

H. V. Fairbanks

The effect of insonation during the solidification of cast iron was investigated. The results are illustrated in the microphotographs shown in Figure 1. Some refinement of the graphite can be noted.



Fig. 1. Photomicrographs showing the effect of insonation during the solidification of gray cast iron upon the dispersion of graphite. Magnification is 100X. The dark areas are graphite in the iron matrix.

The microphotograph at the left shows the structure obtained with no insonation. The microphotograph at the right shows the effect of insonation using a frequency of 20,000 cycles per second with 100 watt input to the generator.

A literature survey was made to review the fundamental principles involved in the production of dispersion alloys.

It was concluded that, with the use of the equipment now available, it is impossible to obtain sufficient dispersion of the graphite in iron to warrant further study of this system at this time.

Two projects are to be run concurrently during the coming academic year:

1. Investigation will be made regarding the production of dispersion alloys using ultrasonic energy for mixing the inert dispersion material into the molten matrix metal. The resulting dispersion alloys will then be tested for homogeneity and for pertinent physical properties.

2. Investigation will also be made in regard to possible improvement in homogeneity of the dispersed material in the dispersion alloys with the aid of ultrasonic energy. The alloys will be insonated during heat treatment in the solid state.

Articles will be submitted to appropriate technical journals for publication following completion of the research program. The results of the research, however, will first be written up as theses by the graduate students who have conducted the investigations.

Consideration for a long range major research effort in this area will be dependent upon the results obtained from the present investigations.

10. An Experimental Study of Viscous-Flow Nose-Shape Effects on Impact Tubes.

Richard E. Walters

The project was started June 1, 1964. Progress has been limited to the actual construction of test equipment which is now (September) nearly completed. In the next few weeks calibration of the equipment and initial tests will be performed. Plans have been completed to perform the experiments, correlate the data, and prepare the final report. The findings should be suitable for publication in any of several technical journals concerned with fluid mechanics and a technical note or article will be submitted for publication.

Several possibilities exist for expanding the work of this project into a major research effort. These will depend on unanswered questions posed by the experimental results. The data should form the basis for theoretical and experimental work in impact tube operation, especially when viscous effects are combined with stream turbulence, tube yaw, surface proximity, and velocity gradient effects.

11. A Preliminary Study of the Effect of Strain Rate on the Mechanical Properties of Biological Materials.

James H. McElhaneey

A specially designed testing machine and high frequency response instrumentation for the purpose of obtaining stress-strain information over a wide range of strain rates has been completed. Fifty compression tests of beef bone have been made on this machine and the data analyzed.

Results indicate a wide variation of mechanical properties of bone with strain rate. For example, the ultimate strength is tripled when strain rate is increased from static to 600 per second. The relation between strain rate and ultimate strength appears to be exponential in form and empirical relations have been established.

Future research will evaluate the effect of strain rate on human bone, various bovine muscle tissues, nylon and aluminum. An attempt will be made to develop a mathematical model similar to a three-parameter Kelvin-Voigt model.

A first paper describing this work was presented on August 7, 1946 at the Conference on Engineering and Medicine, at Andover, New Hampshire. A paper describing the entire project and results will be written for publication in the Journal of Applied Physiology.

Results to date have indicated the need for a further large scale study to:

1. Develop general relationships for various classes of biological materials;
2. Explore the nature of maximum and minimum points in these general relationships;
3. Provide more specific data of interest to designers of space vehicles, ejection seats, acceleration couches, etc;
4. Seek an explanation of the nonlinear impedance of systems of biological materials.

12. An Experimental Investigation of the Effects of Hypervelocity Particles on Shielded and Unshielded Cellular Metallic Plates.

E. L. Kemp

As anticipated, the major effort in this project has been directed to the construction of a firing gun facility comprising a

modified 37 mm cannon to be used as a target launcher and an opposed small bore light gas gun that will fire the particles at the target. These opposed firing mechanisms are separated by a specially designed steel vacuum tank to reduce drag on both the target and particle. The entire facility is nearly fifty feet long.

To date, the light gas gun has been fabricated, including a specially designed barrel and firing circuits. Several preliminary charges have been fired to test the reliability and safety of the device. Some "teething" trouble has been encountered in producing a suitable metal diaphragm between the massive breech housing and the barrel which will rupture at a pre-determined pressure. When the diaphragm ruptures the gas escapes into the barrel driving the small simulated meteoroid particle towards the target. Work is in progress to perfect a diaphragm which will allow the high pressures required to develop without danger of gas leakage or failure of the breech block.

Work on the special vacuum tank which is two feet in diameter and approximately fifteen long is substantially complete. The tank has been designed with a ten foot hatch which can be opened after a test to retrieve the target.

A 37 mm cannon and firing base have been procured from Aberdeen Proving Ground together with a supply of shells.

Except for some special machining for the light gas gun the entire facility has been fabricated in the department of civil engineering shop. It is expected that the first preliminary panels will be tested in the next six weeks to check the functioning of the testing apparatus. If this phase is successful, testing of the special panels will follow immediately. It is anticipated that substantially increased velocities will be obtained using the new apparatus. This will provide unique

information on the behavior of honeycomb panels subjected to hyper-velocity particle bombardment. Every effort will be made to publish the results. Douglas Aircraft, Lockheed California, North American Aviation and members of the N.A.S.A. in Houston have all expressed interest in this project.

This apparatus should provide a useful tool for future research and it should provide a most useful asset to our structural research program. It is possible that some of the components of the present device could be utilized in the construction of an even higher velocity device.